Appendix E

Selected Model Assumptions

Reference Case

The Reference Case for this analysis is similar to the reference case for the *Annual Energy Outlook 2000* (*AEO2000*), with the following updates.

- The resource base for conventional natural gas sources in the Rocky Mountain region is lower than in *AEO2000* by 8 percent—the volume estimated to be subject to current environmental and other constraints that preclude industry access.

- In the Unconventional Gas Recovery Supply Submodule, the overall improvement in technology for enhanced coalbed methane recovery is assumed to be 30 percent for this analysis, up from 25 percent in *AEO2000*, and the enhanced technologies are made available in 2010 rather than 2015.

- World oil prices and natural gas wellhead prices in 1999 and 2000 have been updated according to data from the April 2000 *Short-Term Energy Outlook*. The 1999 world oil price is $17.13 per barrel, up from $16.98 per barrel in *AEO2000*, and the 2000 world oil price is $24.36 per barrel, up from $21.16 per barrel in *AEO2000*. The average natural gas wellhead prices in 1999 and 2000 are $2.07 and $2.48 per thousand cubic feet, respectively, revised from $2.12 and $2.17 per thousand cubic feet, respectively, in *AEO2000*.

Rapid and Slow Technology Cases

Two alternative cases were created for this analysis to assess the sensitivity of the projections in the Accelerated Depletion Case to changes in the assumed rates of progress in oil and natural gas supply technologies. To create these cases a number of parameters representing technological penetration in the Reference Case were adjusted to reflect more rapid and slower penetration rates. In the Reference Case, the underlying assumption is that technology will continue to penetrate at historically observed rates. Because technologies are represented somewhat differently, in different submodules of the Oil and Gas Supply Module, the approach for representing rapid and slow technology penetration varies as well. For instance, the effects of technological progress on conventional oil and natural gas parameters in the Reference Case—such as finding rates, drilling, lease equipment, and operating costs, and success rates—were adjusted upward and downward by 50 percent for the Rapid and Slow Technology Cases, respectively (Table E1).

The representations of enhanced oil recovery and unconventional natural gas recovery are described below. All other parameters in the model were kept at their Reference Case values, including technology parameters for other modules, parameters affecting foreign oil supply, and assumptions about imports and exports of liquefied natural gas and natural gas trade with Canada and Mexico.

Enhanced Oil Recovery

Two impacts of technology improvement are modeled to determine the economics for development of inferred enhanced oil recovery (EOR) reserves:

- An overall reduction in the costs of drilling, completing, and equipping production wells as a result of incremental improvements in drilling equipment and procedures, reservoir characterization, completion methods, and operation refinement

- Field-specific penetration of horizontal well technology, which represents a quantum improvement in recovery efficiency.

The specific parameters for the Reference Case and the Rapid and Slow Technology Cases are shown in Table E2.

The percentage of the remaining undiscovered recoverable resource determined to be technically amenable to gas-miscible EOR methods is set for each region at the beginning of the forecast, assuming current technology. The value is assumed to increase over the forecast period with advances in technology (Table E3).

Unconventional Gas Recovery

The Unconventional Gas Recovery Supply Submodule relies on the model's Technology Impacts and Timing functions to capture the effects of technological progress on costs and productivity in the development of gas from deposits of coalbed methane, gas shales, and tight sands. The numerous research and technology initiatives are combined into 11 specific "technology groups" that encompass the full spectrum of key disciplines—geology, engineering, operations, and the environment. The technology groups are characterized for the Reference, Accelerated Depletion, and Rapid and Slow

Table E1. Assumed Annual Rates of Technological Progress in the Reference and Rapid and Slow Technology Cases: Costs, Finding Rates, and Success Rates for Conventional Sources of Oil and Gas

(Percentage Improvement per Year)

Category	Natural Gas			Crude Oil		
	Reference Case	Rapid Technology Case	Slow Technology Case	Reference Case	Rapid Technology Case	Slow Technology Case
Costs						
Drilling						
Onshore	1.29	1.94	0.65	1.29	1.94	0.65
Offshore	2.02	3.03	1.01	2.02	3.03	1.01
Alaska	1.00	1.50	0.50	1.00	1.50	0.50
Lease Equipment						
Onshore	0.59	0.89	0.30	0.59	0.89	0.30
Offshore	1.40	2.10	0.70	1.40	2.10	0.70
Alaska	1.00	1.50	0.50	1.00	1.50	0.50
Operating						
Onshore	0.54	0.81	0.27	0.54	0.81	0.27
Offshore	0.60	0.90	0.30	0.60	0.90	0.30
Alaska	1.00	1.50	0.50	1.00	1.50	0.50
Finding Rates						
New Field Wildcats						
Onshore						
Shallow						
Northeast	0.50	0.75	0.25	0.50	0.75	0.25
Gulf Coast	2.00	3.00	1.00	2.00	3.00	1.00
Mid Continent	3.00	4.50	1.50	2.00	3.00	1.00
Southwest	3.00	4.50	1.50	4.00	6.00	2.00
Rocky Mountain	2.00	3.00	1.00	2.00	3.00	1.00
West Coast	1.00	1.50	0.50	1.00	1.50	0.50
Deep						
Northeast	--	--	--	--	--	--
Gulf Coast	1.00	1.50	0.50	--	--	--
Mid Continent	1.00	1.50	0.50	--	--	--
Southwest	6.00	9.00	3.00	--	--	--
Rocky Mountain	1.00	1.50	0.50	--	--	--
West Coast	--	--	--	--	--	--
Offshore	6.00	9.00	3.00	2.00	3.00	1.00
Other Exploratory						
Onshore						
Shallow	0.00	0.00	0.00	2.88	4.32	1.44
Deep	4.72	7.08	2.36	--	--	--
Offshore	4.14	6.21	2.07	4.14	6.21	2.07
Developmental						
Onshore						
Shallow	0.27	0.41	0.14	2.50	3.75	1.25
Deep	1.61	2.42	0.81	--	--	--
Offshore	4.14	6.21	2.07	4.14	6.21	2.07
Success Rate						
Exploratory	0.50	0.75	0.25	0.50	0.75	0.25
Developmental	0.00	0.00	0.00	0.00	0.00	0.00

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Table E2. Assumed Rates of Technological Progress for Enhanced Oil Recovery Techniques

Item	Reference Case	Rapid Technology Case	Slow Technology Case
Drilling, Completion, and Equipping Costs (Percentage Decline per Year)	2	3	2
Horizontal Well Technology Penetration			
Start Date	1995	1995	NA
Penetration Period (Years)	40	20	None
Penetration Rate (Percent per Year)	2.5	5.0	0
Maximum Penetration of Inferred reserve Base (Percent)	90	90	0

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Table E3. Assumed Rates of Technological Progress for Gas-Miscible Enhanced Oil Recovery Techniques
(Annual Percentage Increase in Recoverable Resource)

Region	Reference Case	Rapid Technology Case	Slow Technology Case
Gulf Coast (Region 2)	2.5	3.5	0.0
Midcontinent (Region 3)	2.0	3.0	1.0
Southwest (Region 4)	2.0	3.0	1.0
Rocky Mountain (Region 5)	2.0	3.0	1.0

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Technology Cases as summarized in Table E4. The 11 technology groups are described below:

1. **Basin Assessments:** Basin assessments increase the available resource base by (1) accelerating the time that hypothetical plays in currently unassessed areas become available for development, and (2) increasing the play probability for hypothetical plays—that portion of a given area that is likely to be productive.

2. **Play-Specific, Extended Reservoir Characterizations:** Extended reservoir characterizations increase the pace of new development by accelerating the pace of development for emerging plays, where projects are assumed to require extra years for full development relative to plays currently under development.

3. **Advanced Well Performance Diagnostics and Remediation:** Well performance diagnostics and remediation expand the resource base by increasing reserve growth for already existing reserves.

4. **Advanced Exploration and Natural Fracture Detection Research and Development:** Exploration and natural fracture detection research and development increases the success of development by (1) improving exploration and development drilling success rates for all plays, and (2) improving the ability to find the best prospects and areas.

5. **Geology/Technology Modeling and Matching:** Geology/technology modeling and matching matches the "best available technology" to a given play with the result that the expected ultimate recovery (EUR) per well is increased.

6. **More Effective, Lower Damage Well Completion and Stimulation Technology:** Improved drilling and completion technology improves fracture length and conductivity, increasing the EUR per well.

7. **Targeted Drilling and Hydraulic Fracturing Research and Development:** Targeted drilling and hydraulic fracturing research and development results in more efficient drilling and stimulation, which lowers well drilling and stimulation costs.

8. **New Practices and Technology for Gas and Water Treatment:** New practices and technology for gas and water treatment result in more efficient gas separation and water disposal, which lowers water and gas treatment operation and maintenance (O&M) costs.

9. **Advanced Well Completion Technologies:** Research and development in advanced well completion technologies such as cavitation, horizontal drilling, and multi-lateral wells (1) defines applicable plays, thereby accelerating the date such technologies are available, and (2) introduces an improved

Table E4. Assumed Rates of Technological Progress for Unconventional Gas Recovery in the Reference, Accelerated Depletion, and Rapid and Slow Technology Cases

Technology Lever	Item	Resource Type	Reference Case	Accelerated Depletion Case	Rapid Technology Case	Slow Technology Case
Reservoir Characterization and Well Performance Technology						
1. Basin Assessments	Date available	All types	2016	NA	2011	NA
2. Play-Specific, Extended Reservoir Characterizations	Development pace	Tight gas sands	-1.25 yr per year	-0.5 yr per year	-2.0 yr per year	-0.5 yr per year
	Development pace	Coalbed methane	-1.0 yr per year	-0.5 yr per year	-1.5 yr per year	-0.5 yr per year
	Development pace	Gas shales	-1.0 yr per year	-0.5 yr per year	-1.5 yr per year	-0.5 yr per year
5. Geology/Technology Modeling and Matching	EUR per well	All types	5%	NI	5%	NI
6. More Effective, Lower Damage Well Completion and Stimulation Technology	EUR per well	All types	10%	5%	10%	5%
Optimization and Cost Reduction Technology						
3. Advanced Well Performance Diagnostics and Remediation	Reserve growth	Tight gas sands	2.0% per year	2.0% per year	3.0% per year	1.0% per year
	Reserve growth	Coalbed methane	3.0% per year	3.0% per year	4.5% per year	1.5% per year
	Reserve growth	Gas shales	3.0% per year	3.0% per year	4.5% per year	1.5% per year
7. Targeted Drilling and Hydraulic Fracturing Research and Development	Cost per well	All types	-10%	-10%	-15%	-5%
8. New Practices and Technology for Gas and Water Treatment	Cost per Mcf	All types	-20%	-20%	-30%	-10%
Access to Resources						
11. Mitigation of Environmental Restraints	Acreage available	All types	Removed in 50 years (1%/yr)	NI	Removed in 25 years (2%/yr)	NI
Exploration/Breakthrough Technology						
4. Advanced Exploration and Natural Fracture Detection Research and Development	E/D success rate	All types	+0.25% per year from 2000	NI	+0.50% per year from 2000	NI
	Exploration efficiency	All types	Identify "best" 30% by 2017	NI	Identify "best" 30% by 2007	NI
9. Advanced Well Completion Technologies						
Horizontal Wells	Recovery efficiency	Tight gas sands	+10% in 2011	NI	+15% in 2011	NI
Advanced Cavitation	EUR per well	Coalbed methane	+20% in 2011	NI	+30% in 2006	NI
Multilateral Completions	Recovery efficiency	Gas shales	NI	NI	+15% in 2011	NI
10. Other Unconventional Gas Recovery Technologies	EUR per well	Tight gas sands	+10% in 2021	NI	+10% in 2016	NI
Enhanced Coalbed Methane Recovery Efficiency	Recovery efficiency	Coalbed methane	+30% in 2015	NI	+45% in 2010	NA
Enhanced Coalbed Methane O&M Costs	Cost per Mcf	Coalbed methane	$1.00 per Mcf, incremental	NA	$0.75 per Mcf, incremental	NA
Other Technology		Gas shales	NA	NA	NA	NA

NA = not available. NI = no improvement.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

version of the particular technology, which increases the EUR per well.

10. Other Unconventional Gas Recovery Technologies: Other unconventional gas recovery technologies, such as enhanced coalbed methane and enhanced gas shale recovery, introduce dramatically new recovery methods that (1) increase the EUR per well, (2) become available at dates accelerated by increased research and development, and (3) increase operation and maintenance (O&M) costs (in the case of coalbed methane) for the incremental gas produced.

11. Mitigation of Environmental Constraints: Environmental mitigation removes development constraints in environmentally sensitive basins, resulting in an increase in basin areas available for development.